

NOTE: We recommend using the aluminum block in your first attempt at making the Turner's cube. The aluminum is more forgiving and less expensive on which to practice.

**SHERLINE
PRODUCTS**
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Making a "Turner's Cube" on a Sherline Lathe

T1000 (Kit without 4-jaw chuck)
T1076 (Kit with P/N 1076 4-jaw chuck)

Making a Turner's Cube

By Karl Rohlin

I was looking for a project to make on our Sherline Lathe to go along with our Christmas special. I wanted something that was not too big or too difficult, yet challenging enough to possibly spark the imagination of the younger generation...a machinist's Christmas ornament if you will. Something that could be passed down from Grandfather or Father, to Grandson or Son. Something that could tease the young mind of today, and bring back memories of the maker in the future.

The project that I decided to make was the Turner's Cube. It's a set of smaller cubes that are captured inside of larger cubes. I chose a size that would be small enough to possibly put on a key chain or other keepsake. This smaller size is also perfect for making on a Sherline Lathe. It can be made in a few hours, and it only requires a few tools.

These instructions are for a $\frac{3}{4}$ " cube. This kit includes $\frac{3}{4}$ " cubes of aluminum and brass. I suggest you practice on the aluminum first and then make a final cube from brass once you have a feel for how it's done.

I made this part on our Sherline lathe. I used a 4-jaw "self-centering" chuck (P/N 1076). You can use a 4-jaw "independent" chuck (P/N 1030 or 1044) if you wish, however, the self-centering chuck is much faster and requires less indicating.

Kit Tooling List

| NO. REQ. | PART NO. | DESCRIPTION |
|----------|----------|---|
| 2 | | $\frac{3}{4}$ " cube raw stock (1 ea. 6061-T6 alum. and brass) |
| 1 | 30260 | #2 Center Drill |
| 1 | 30310 | 1/8" Drill |
| 1 | 3061 | Boring Tool |
| 1 | T3061 | Boring Tool (Custom ground to make an "undercut tool") |
| 1 | 7600 | 3/8" Tool Post |
| 1 | T10001 | 1.25" Diameter Key Ring (spring-tempered steel) |
| 1 | 1076 | 3.1" 4-Jaw Self-Centering Chuck (included with T1076 kit only) |

Let's get started

I originally made this out of $\frac{5}{8}$ " square stock, but the wall thickness was too thin on the outer cube. Therefore, I am going to increase the size of the outer cube to $\frac{3}{4}$ " but leave the inside cubes the same size. The only change will be the bore depths to compensate for the additional .062" of material.

Calculations

We are going to make a three-cube Turner's Cube. I am going to use the steps and calculations from the $\frac{5}{8}$ " cube and alter the depth of cut for a $\frac{3}{4}$ " outer cube.

1. If the outer cube is .625" square, and I want three cubes. I will divide .625 by 3 to acquire the size of my three cubes. ($.625/3 = .209$) The inner cube will be .209" square, the middle cube will be .418" square, and the outer cube at .625" square.
2. Next we figure out the bore sizes. The bore size has to be smaller than the diameter of the outer corners of each cube. Therefore we must first calculate the outer corner diameter of each cube. We do this by using the Pythagorean Theorem which is $A^2 + B^2 = C^2$.

Inner Cube Diameter = $.2092 + .2092 = .08736$, the square root = .2955" dia.

Middle Cube Diameter = $.4182 + .4182 = .3494$, the square root = .5911" dia.

In order to keep the cube from coming out of the hole, I will make each bore undersized by approximately .050".

Inner Cube Bore Diameter = .240"

Middle Cube Bore Diameter = .540"

3. Now we need to figure out the undercut diameter. For this diameter I added approximately .04" to .05" to each Cube Diameter.

Inner Cube Undercut Diameter = .335"

Middle Cube Undercut Diameter = .631"

4. Now we need the bore depths. To do this take the size of the outer cube, subtract the size of the cube that you are boring to ($.750" - .209" = .541"$). Now divide that answer by 2 to get the depth of the bore ($.541" / 2 = .270"$). For the middle cube ($.750" - .418" = .332" / 2 = .166"$).

Therefore, we are going to bore .240" dia. x .270" deep, and .540" dia. x .166" deep.

Note: When you bore your holes, go .003" less than the final depth and then use the undercut tool to clean up the last .003". This will get rid of any chatter marks or chip marks and leave a nice finish on the side of each cube.

Final Dimensions

Inner Cube .209" square: Bore .240" dia. x .267" deep. Undercut at .325" dia. x .270" deep.

Middle Cube .418" square: Bore .540" dia. x .163" deep. Undercut at .620" dia. x .166" deep.

Machining sequence

As with all machined parts, the machining sequence (order of operations) is critical and dictates the quality and accuracy of the finished part.

Note: these instructions are written with the assumption that you have already machined your part into a $\frac{3}{4}"$ square. If you don't have a Sherline Mill to do this operation on, you can hold the stock in your 4-jaw chuck and face opposite sides until your part measures $\frac{3}{4}"$. Since you have $\frac{3}{4}"$ square stock, you will only need to machine the saw cut ends of the stock to size. Use the jaws to hold the part by the extruded surfaces. Push the stock into the chuck "lightly" so the jaws can hold the part square. Turn the spindle on to check for excessive runout. Face the first end just enough to clean up the surface. (See Figure 1.) Now the faced end of the stock and the extruded sides of the material should be perpendicular. Now flip the part around and push the finished face of the stock into the face of the chuck with more pressure. This will locate the stock against the chuck and now you can face the other side to the $\frac{3}{4}"$ finish dimension.

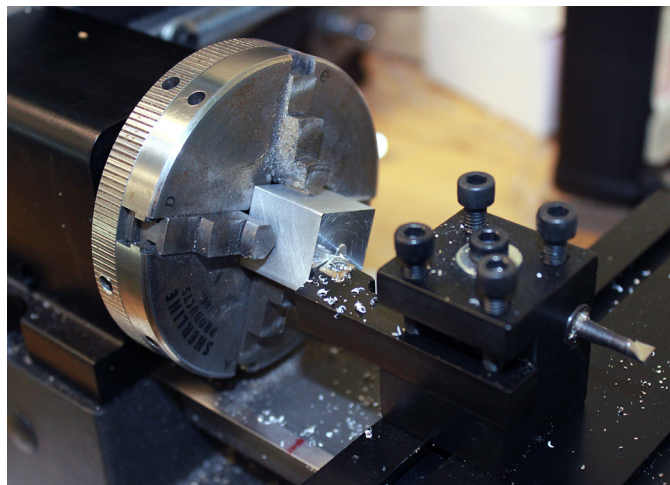


FIGURE 1—Facing the first saw-cut surface.

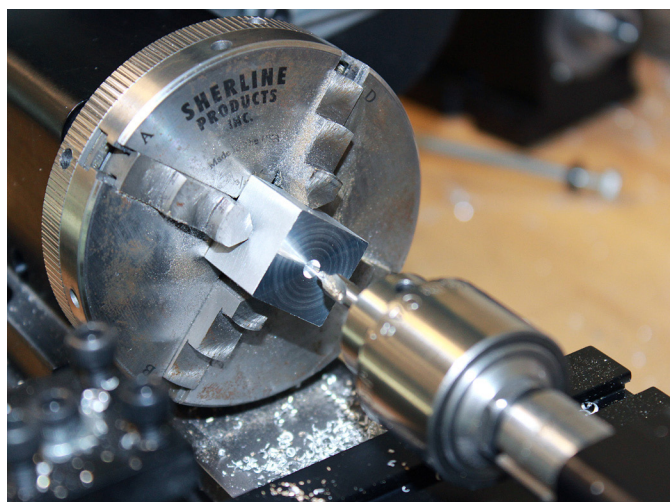


FIGURE 2—Center drilling the first side.

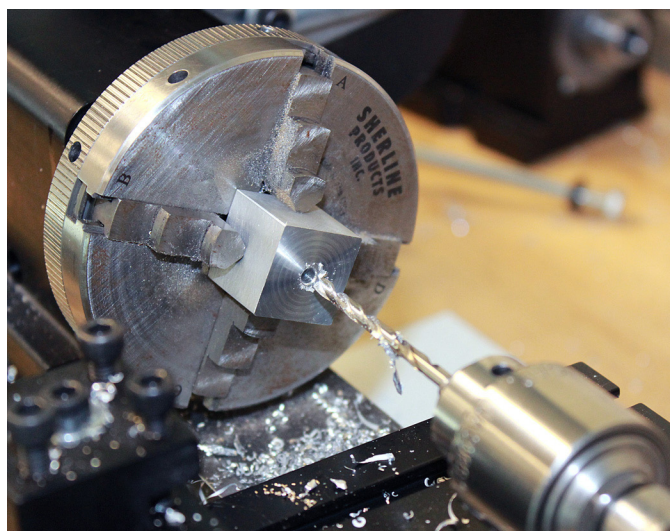
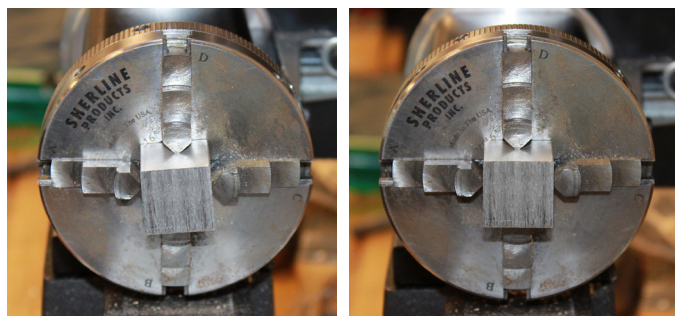


FIGURE 3—Drilling the first side with the 1/8" drill.

1. Center drill and drill the 1/8" hole through the part from three sides. (See Figures 2 and 3.)
2. Rough and finish bore the .240" diameter x .267" deep on all sides. Machine the cube by cutting opposite sides (if it were numbers on a dice you would machine the side with (1) and then the side with (6) etc.). (See Figure 4.)



WRONG

RIGHT

Tip: Turn the stock back and forth as you tighten the chuck. Even though you are holding a four-sided part with a 4-jaw chuck. You still need to wiggle the part as you tighten the chuck to ensure that the sides are square to each jaw and that you are holding the stock at the center of each side. If they are not held square to each jaw, the part will work its way loose during the machining process, and it will come out of the chuck. (See photos above.)

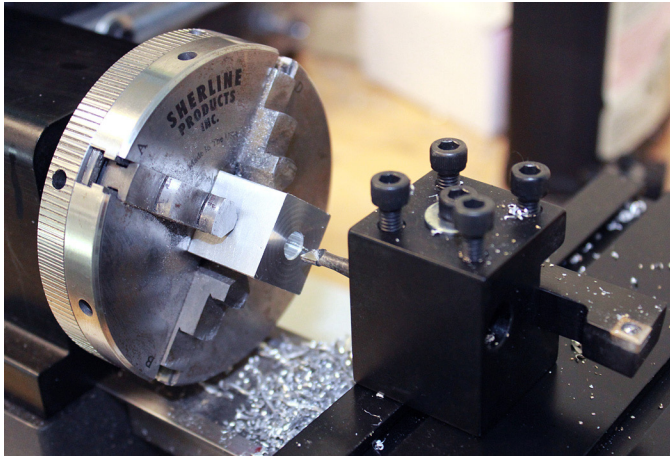


FIGURE 4—Boring the first hole to .240 diameter and .267" deep.

NOTE: The 30610 boring bar will fit into the 1/8" hole. However, it will be cutting almost to size when it is positioned so it will not rub on the back side of the 1/8" hole. Therefore, you may want to grind a little bit off of the back side of the boring bar for clearance. This will still leave plenty of cutting surface on the boring bar. This boring bar was also made to fit in our Boring Head (P/N 3054). Because of this the flat on the shank is on the side of the boring bar instead of the top which is where it would be if it was made to be used on the lathe. Because there isn't a flat to locate the cutting edge of the boring bar "on centerline", you will need to turn the boring bar until the cutting edge is on centerline. Then lock it in place with the 10-32 screw on the P/N 7600 Tool Post. The screw will be locating on the round part of the shaft rather than on a flat, which is not generally acceptable. However, you will be taking light cuts in soft material which should not exert enough force on the tool to move it in the holder. I would recommend .020" radius depth of cut to rough, and .010" depth of cut for the finish pass.

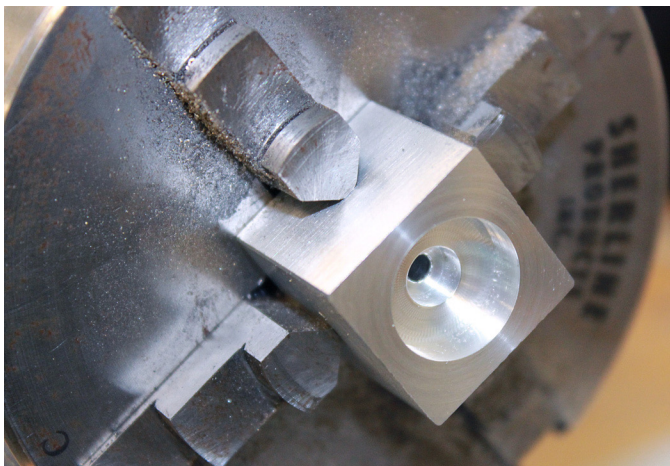


FIGURE 5—The second hole is bored to .540" diameter and .163" deep.

3. Rough and finish bore the .540" diameter x .163" deep on all sides. (See Figure 5.)

Note: Again, use .020" depth of cut to rough and .010" depth of cut to finish the bore to size.

Note: Chamfer the bored holes. This will make your part look much nicer and remove burrs that you will otherwise need to remove by hand. You already know what the handwheel settings are for each depth and diameter of each bored hole. Using the same boring bar, bring the boring bar out .010" larger than the bore diameter. Then move the boring bar into the top surface of the bore (this is done with the spindle on). I use the handwheel to move the cutter close to the top surface, and then I creep up on it until I hear it touch. Now you have a chance to do some free hand work on a "non critical" surface. Simultaneously move the crossslide handwheel in .010" and the Z axis handwheel in .010". This will cut a 45° x .010" chamfer on the bored hole. If your angle is off a little, or your chamfer size is a bit large or small no one is going to notice. It's just a chamfer. However, this gives you an opportunity to practice some free-hand machining, and your ability to move two axes simultaneously will probably get pretty good by the time you get to the last holes. It's a small step towards becoming an artist, as well as a machinist. (If you really want to test your free hand ability, chuck up a piece of stock and try to machine tapers and radii.)

Use the #2 center drill to chamfer the 1/8" hole on the inner cube.

4. Finish face and undercut five of the six sides of the .209" cube. For this operation you will be using the hand ground "undercut tool" that was made from the second 3061 Boring Tool (See Fig. 7.) Undercut to .335" diameter at .270" deep. At the .270" depth, you will be taking a .003" finish pass on the face of each side of the cube. **IMPORTANT! Do not undercut all six sides!** I suggest marking one side with a magic marker so you will know which one to leave for last. (See Figure 6.)

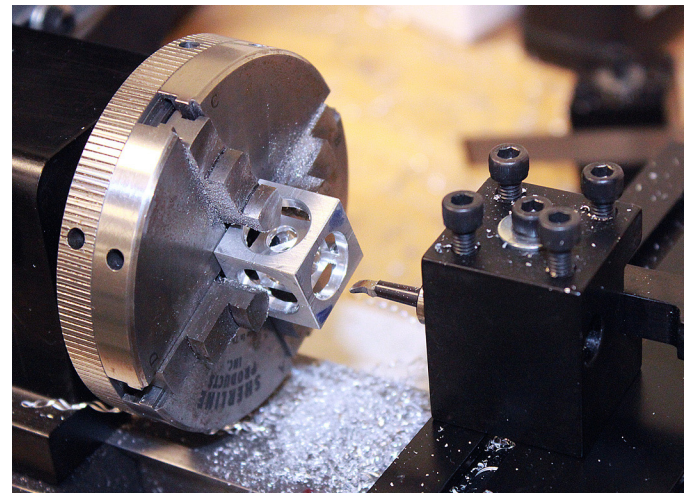


FIGURE 6—The special undercut boring tool P/N T3061 is used to release the inside cubes.

5. **IMPORTANT:** On the sixth side you can't just turn the spindle on and undercut to the final diameter. The material on the sixth side is the only thing holding the .209" cube in place. Once you cut it loose it will bounce around inside the middle cube and cause dents and possibly ruin the part or cutter. In order to undercut to



FIGURE 7—The tip of the P/N T3061 boring tool is shaped to undercut the final bore diameter to release the inner cubes.

the final diameter without any damage to the part, you will need to make the final cuts by turning the chuck by hand. Because the Sherline lathe speed control can go as low as 10 or 15 RPM, it is advisable to turn the speed down low for the start of the undercut. When you get within .010" to .020" of the final undercut diameter, then turn the spindle off and turn the chuck by hand. Gradually move the cutter out by .001" and turn the chuck a couple of revolutions between each move. The inner cube will be cut free of the part and fall undamaged to the bottom of the pocket.

6. Now finish face and undercut five of the six sides of the .418" cube. Undercut to .631" diameter x .166" deep. Again, cut only five sides. Then follow the above procedure to finish the last side.
7. Now your Turner's Cube is finished. Use some jeweler's files to remove the burrs from the inner cubes. You can use a file or deburring tool to remove the sharp edges on the outer cube. If you want nice chamfers on the outer corners, you can do this when you square up the stock on your mill. A 90° chamfer bit or 90° spotting drill will work fine.

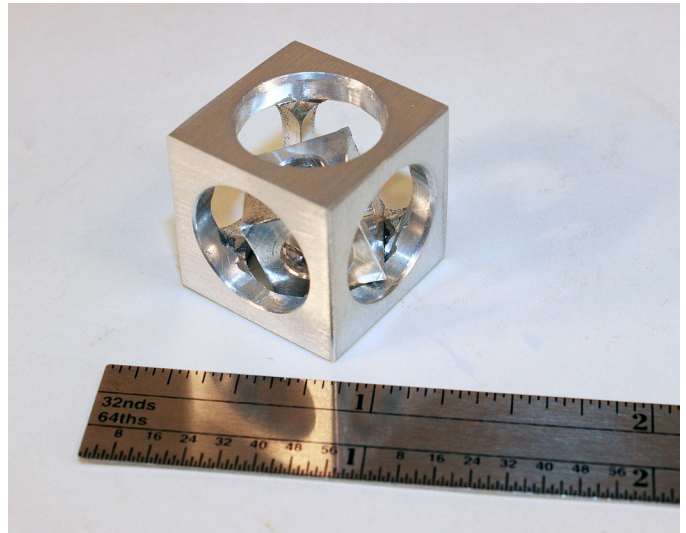


FIGURE 8—The finished aluminum cube after deburring. Challenge your friends to figure out how it was made.

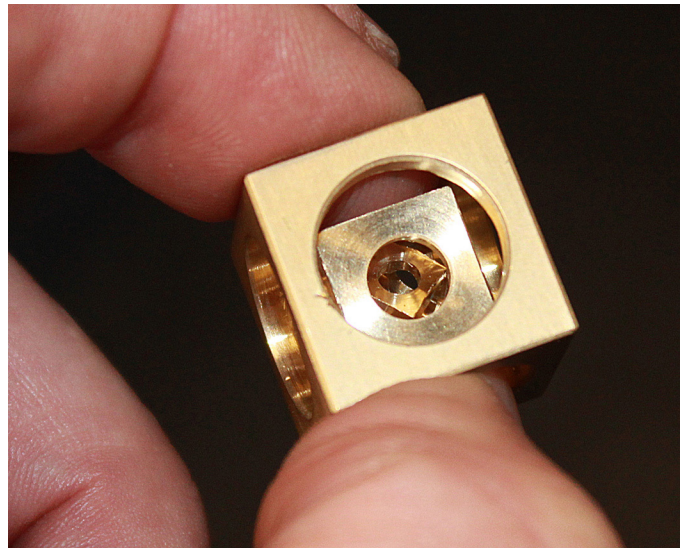


FIGURE 9—Here is a cube made from brass using the same tools and methods. It is heavier and has a richer look—a more impressive piece of work.